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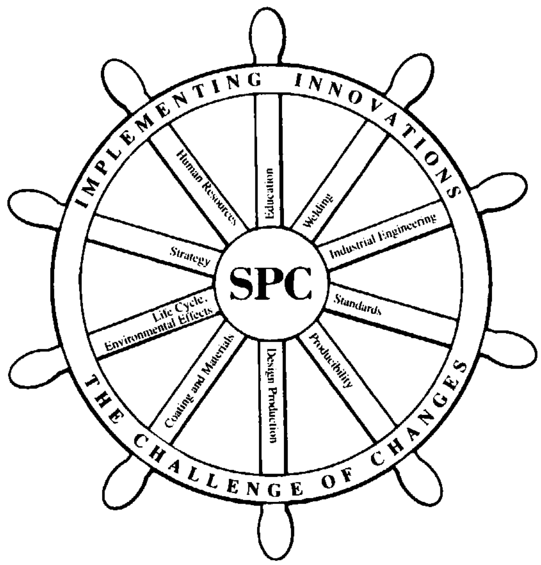

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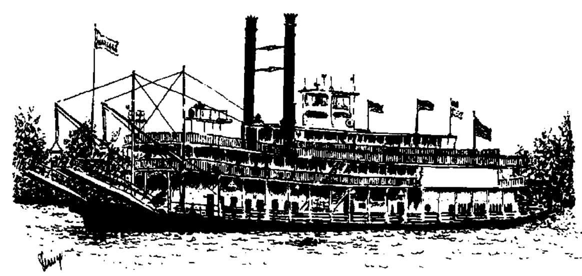

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An Approach to a New Ship Production System Based on Advanced Accuracy Control

No. 7A-1

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ABSTRACT

Mechanizing and automating have been accelerated in shipbuilding in order to respond to current situations such as decreasing numbers of skilled workers and increasing difficulty in recruiting new workers.

For effective implementation of mechanization or automation, current hull fabrication systems should be reviewed in order to make them suitable for intended mechanization or automation because geometric inaccuracy hampers implementation and necessitates voluminous work adjustments.

This report proposes a new ship production concept based on using advanced methods to keep the accuracy of the hull structure at a high level, such as numerical simulation of heat deformation in burning, welding and bending, mechanizing to reduce deviations dependent on human skill, and a three-dimensional measuring system for advanced accuracy control together with some examples of its actual application to checking block shape at the assembly stage and shipwrighting at the erection site.

INTRODUCTION

To maintain the competitiveness of a shipyard bearing the hardships surrounding the Japanese shipbuilding industry mentioned in the abstract, the extensive application of mechanization and automation is recognized to be indispensable at Ishikawajima-Harima Heavy Industries Co., Ltd, (IHI) and this can only be realized by upgraded accuracy. From this standpoint, to make an accurate block and to erect it accurately are the major task of current hull personnel in the shipyard.

This paper describes the recent efforts of how the company is rising to the challenge of accuracy of hull structure.

RECOGNITION OF THE PROBLEM

Since the latter half of 1950s when the idea of quality control was introduced in Japan, hull accuracy control concepts have been developed and widely used in each stage of hull work and with this a remarkable productivity improvement has resulted. However, looking at the final goal of having assembled blocks fitted and welded at the erection site without any remedial adjustment, it must be said that the present situation is still far from ideal.

Some recent analyses at the shipyards are explained below to demonstrate the current situation.

Manhour Analyses on Fitting and Welding at Erection Stage

Fig. 1 shows the percentages of expended manhours of fitting and welding work in the hull erection stage based on random sampling carried out in one shipyard recently.

1) Fitting. It is found that main work (essential tacking work) accounts for only 1/6 of the total fitting manhours, while manhours for adjustment work, such as trimming or back-stripping for correction of inaccuracy and

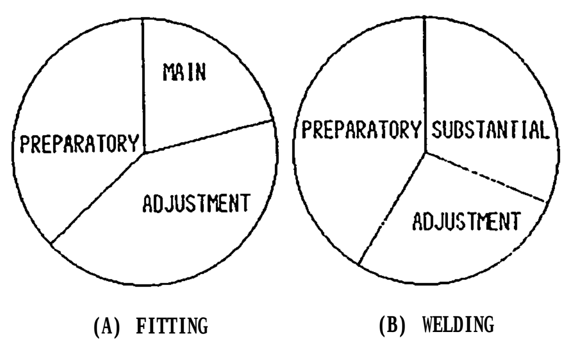


Fig.1 RANDOH SAMPLINC ANALYSIS OF ERECTION WORK

additional fitting of pieces for hammering or jacking, account for nearly 1/2, and manhours of preparatory work, such as cleaning after work, movement to a next work spot and preparation of tools or jigs, account for nearly l/3. It is obvious that the shipyard's target is to eliminate adjustment work, which accounts for half of the total fitting manhours.

2) Welding. As it can be seen, only 1/3 of the total welding manhours are used for substantial welding. Another 1/3 are expended by the preparatory work, such as preparation of tools, cleaning after work and movement to a next work spot, while the remaining 1/3 are consumed by various work making adjustment, such as welding of carried-over weld from assembly, remetaling to get neat edge-preparation, grinding for finishment and so on.

In addition, though it was difficult to analyze accurately, it was obvious that some portion of the substantial welding manhours in Fig. l(B) were expended for depositing excess filler metal due to wider gaps very often seen at joints. The influence of an inaccurate butt joint to the increased welding time is shown in Fig. 2. It is obvious that substantial manhours can also be saved, as well as eliminating manhours for the adjustment work, by improved accuracy.

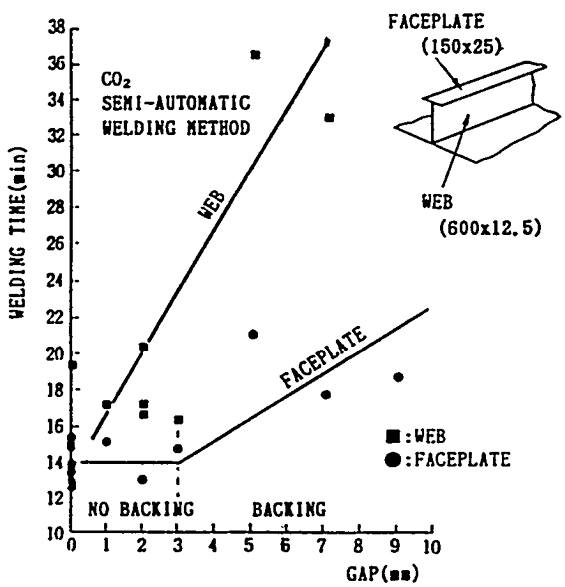


Fig.2 INCREMENT OF WELDING TIME DUE TO JOINT GAP AT ERECTION BUTT

INTRODUCTION OF A THREE-DIMENSIONAL ANALYSIS SYSTEM

As the existing measuring method was linear and planar, deflection and twisting of the three-dimensional blocks could not be accurately checked. The necessity for an instrument capable of measuring three-dimensional blocks of over 10 meters square within an accuracy of several millimeters has been sought for many years. The development of a new measuring technique was taken up in 1982 by the working group for three-dimensional coordinates measurement in the Super Modernization Committee of the Shipbuilders Association of Japan, with the participation of the following five companies: SOKKIA CO., LTD. as an instrument manufacturer, IHI and other three shipyards.

At the beginning, efforts were made to examine the applicability of two types of instruments, an electronic theodolite based on a triangular measurement method and an electronic distance-angle measuring instrument. It was found to be difficult to keep an accurate distance between the two instruments essential for the triangular measuring method. Moreover, due to the instability of the power source, inconvenience of transportation, and the requirement for three or more measurement technicians, it was decided not to take the dual theodolite and to concentrate to develop the application of the distance-angle measuring instrument.

During five years' effort of the working group, the distance-angle measuring method was proved to be applicable, subject to further improvement of the instrument for more accurate measurement and easier handling. After the working group dissolved, the manufacturer continued the efforts and finally reached "NET 2" as a product model in 1989 and "MONMOS" as a total measuring system in 1990, which are actually used in some shipyards in Japan.

The three-dimensional measuring instrument NET 2 was introduced in a Tokyo shipyard immediately after it came into use. Since then a hull block measuring system (hereinafter called the three-dimensional analysis system) by a personal computer incorporated with the MONMOS system has been developed so as to get the actual shape of blocks on a CRT. Other shipyards in the company have also introduced the MONMOS and another application for the ship repair field has been established. That is, to measure actual

shell form in the vicinity of damaged shell plates for the purpose of defining the shape of replacement sections.

The MONMOS System

The following is an outline of the MONMOS system. The MONMOS system consists of a measuring instrument and a control terminal for data control. (See Fig. 3)

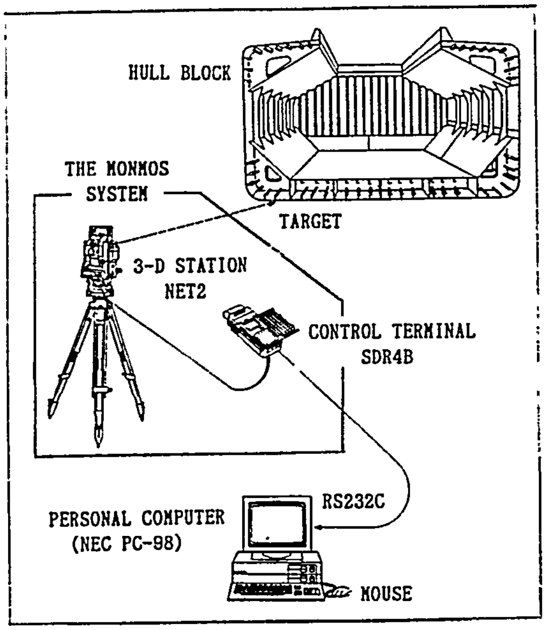


Fig.3 CONFIGURATION OF THE THREE-DIMENSIONAL ANALYSIS SYSTEM

Measurement	; Distance and Angle measurement using near-infrared rays.
Measuring accuracy	; Angle ±2 second Distance $\pm(1+2\times10^{-6}D)$mm Where D is measuring distance in millimeter.

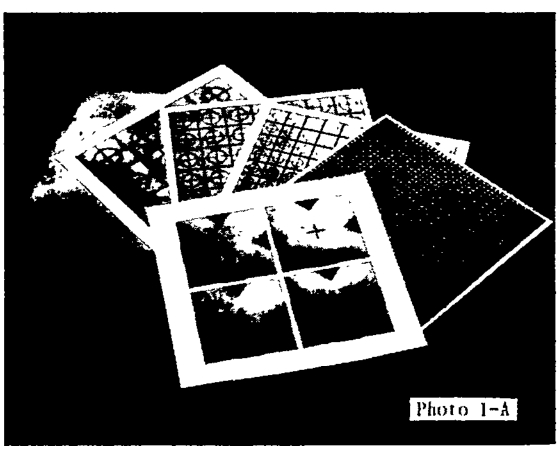
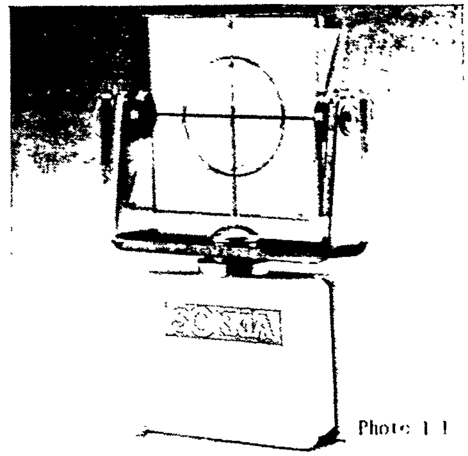


Photo 1-A

Measurable distance	; 2 to 100 meters
Target for the ray	; Microprism reflection sheet (10 to 90mm square), Rotary target (See Photos 1-A and 1-B) and etc.



Measuring principle	; Triangulation by measuring two sides distances (I-O and I-Pi) and included angles (vertical angle and horizontal angle) (See Fig. 4) a. The vertical direction is defined to be the Z-direction. b. The first measuring point (0) is defined to be the origin of the coordinates axis. c. The X-direction is

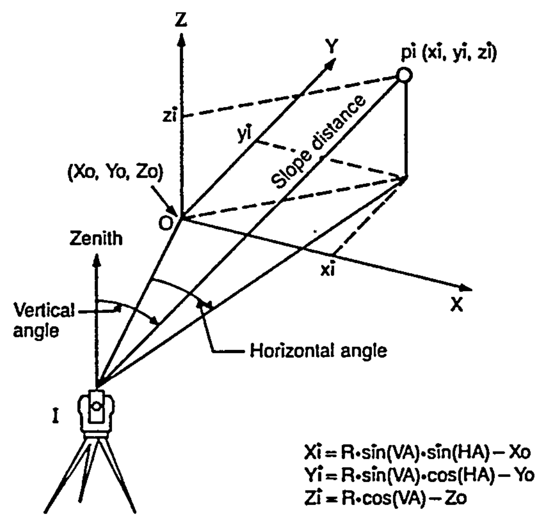


Fig.4 MEASURING PRINCIPLE

defined by the second measuring point and the X-axis is defined on the X-Z plane at normal to Z-axis.

d. Subsequent measured values are converted into coordinate values (X, Y, and Z) and recorded in the control terminal.

The main features of the system are as follows.

a. Measurements can be carried out by one person because one instrument is capable of measuring any size.
b. Coordinates can be combined, i.e. measurement of the back side which cannot be seen is possible by the function that stores measured values as coordinate values. Measurement can be continued with the same coordinate axis by measuring two known points (for example A and B in Fig. 5) even after moving the instrument to another point.
c. Since the measured values are recorded as coordinate values, various kinds of numerical analyses are possible by development of analyzing software.

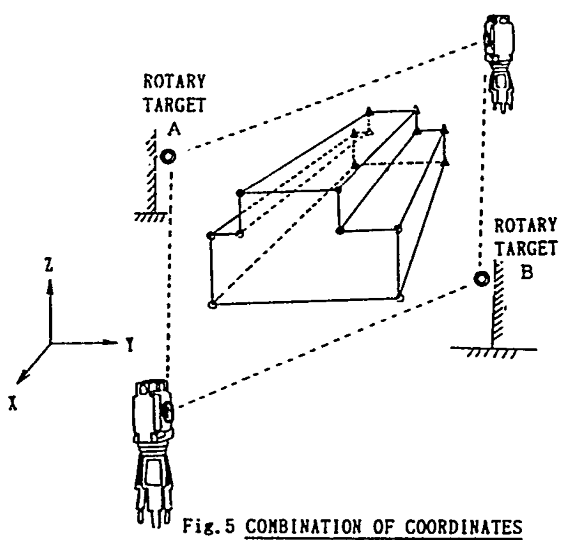


Fig.5 COMBINATION OF COORDINATES

Outline of the Three-dimensional Analysis System

For a long time after the introduction of the hull accuracy control concept in the company, the activity of accuracy control on assembled blocks was limited to measuring length, breadth or height by a linear tape-measure for later evaluation by manual data analysis.

When more precise blocks were called for, the traditional measuring method was not sufficient and measurement of points on any position of a block in terms of coordinate values was highlighted. But the measured points could be more than a hundred (infinitely great theoretically) and automatically the aid of calculation software became necessary to get various measured dimensions required for comparison with design data.

Thus, the company's three-dimensional analysis system was developed to comply with the above necessity with extensive applications for shipwright (this word is used to mean adjusting of a block's position properly after the block was erected and before it is fitted with adjacent blocks.) at the erection stage, the process of which is explained in Fig. 6 and summarized below.

a. Points on a block to be measured are specified based on a standard prepared and updated through experience.
b. Measured coordinates in a local axis are converted into coordinates in the ship's axis for comparison with design data. The conversion is generally carried out using three control points which are defined on a block and matched with the designated position in the ship's axis. When deviation from design data after conversion is found to exceed tolerances on some points due to improper matching by the above procedure, further adjustment by means of small rotation or parallel movement for closer matching can be carried out by manual operation in order to get smaller deviations.
c. Correction work on a inaccurate block is carried out based on the deviation from the above mentioned process taking into account of a result of a simulation for forecasting joint condition with adjacent blocks. After adjacent blocks are erected, a simulation of the joint condition between those erected blocks and this assembled block, using the shipwright data of those blocks and the measured data of this block is generally carried out, whenever this block is accurate or not.
d. The forecasted joint condition data by the above-mentioned simulation are used as a instruction for shipwright.

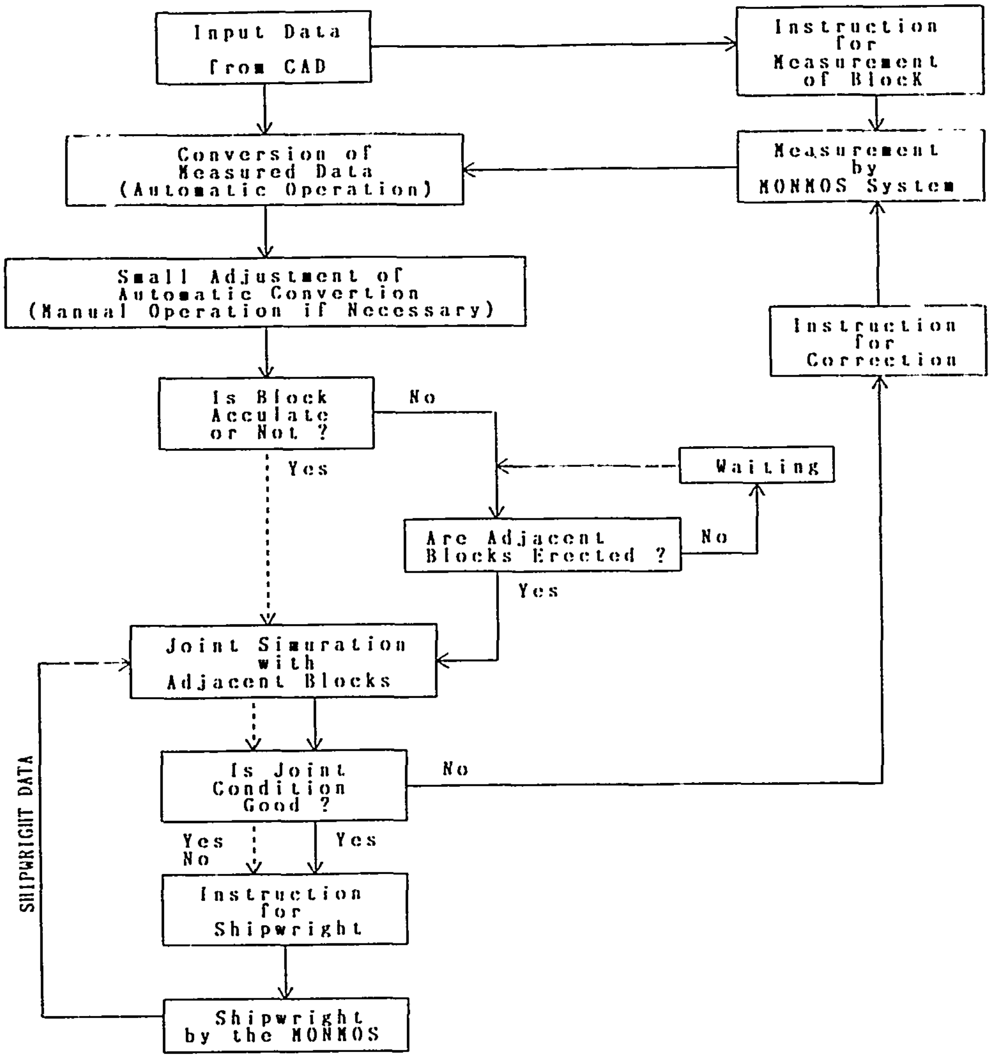


Fig. 6 PROCESS FLOW OF IHI'S THREE-DIMENSIONAL ANALYSIS SYSTEM

Example of Measurement and Analysis on an Assembled Block

The following is an example of using the system on **33,000** DWT Bulk Carrier blocks.

Positioning of Targets. Reflection targets were attached on more than **80** positions covering four sides and root or top of transverse webs and longitudinal on an assembled block on the ground, rotary targets were set on two points (for example, A and 13 in Fig. 7) for the combination of measured data at different locations of the instrument.

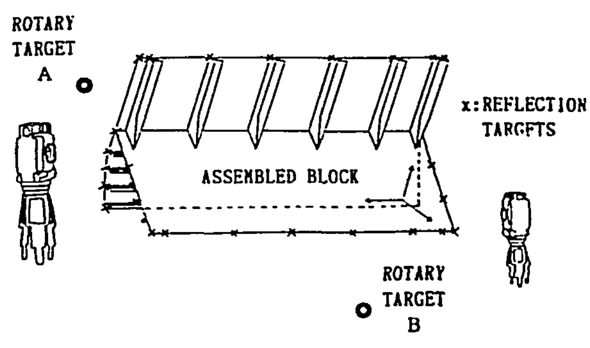


Fig.7 POSITIONING OF TARGET

Measured results. Measured data were transferred into the analysis system and converted into the ship's axis. Calculated results were illustrated on the CRT as shown in Fig. 8.

Evaluation of the results. Figure 9 is an illustration of a displayed results for the explanation purpose.

a. The block length was longer by as much as 14mm at the top but was nearly normal at the middle and bottom. Bigger discrepancy of top length in this case was attributed to

SHIP NO :IHI
FILE NAME:GSL8P. SDR

	STANDARD	LIMIT
LENGTH	± 3	± 5
BREADTH	± 3	± 5
HEIGHT	± 2	± 3
LEVEL	7	15

NO		(mm)	ERROR
1	MEMO	F-2	
	L	12750.0	0.0
	B	11986.0	0.0
	H	6335.0	0.0
2	MEMO	A-2	
	L	-2.0	+2.0
	B	14870.0	0.0
	H	5540.0	+4.0
3	MEMO	F-10	
	L	12753.0	+3.0
	B	7449.0	-1.0
	H	1852.3	-9.7 ▲

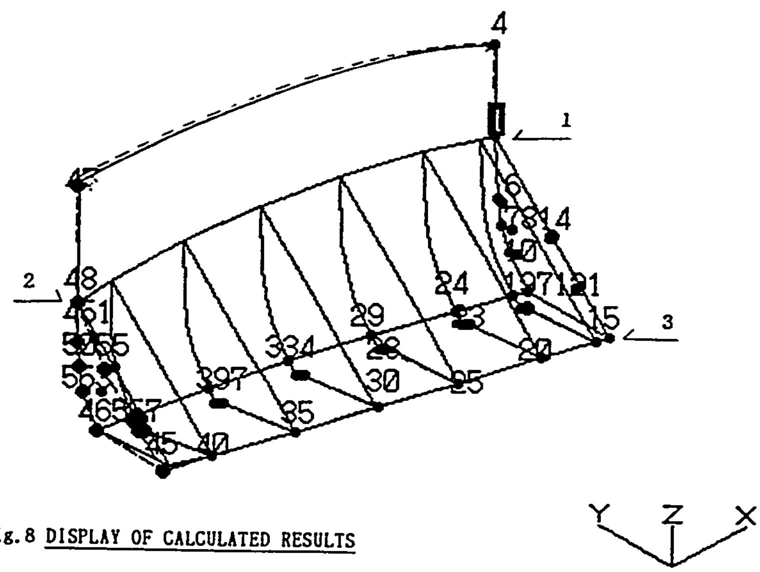


Fig. 8 DISPLAY OF CALCULATED RESULTS

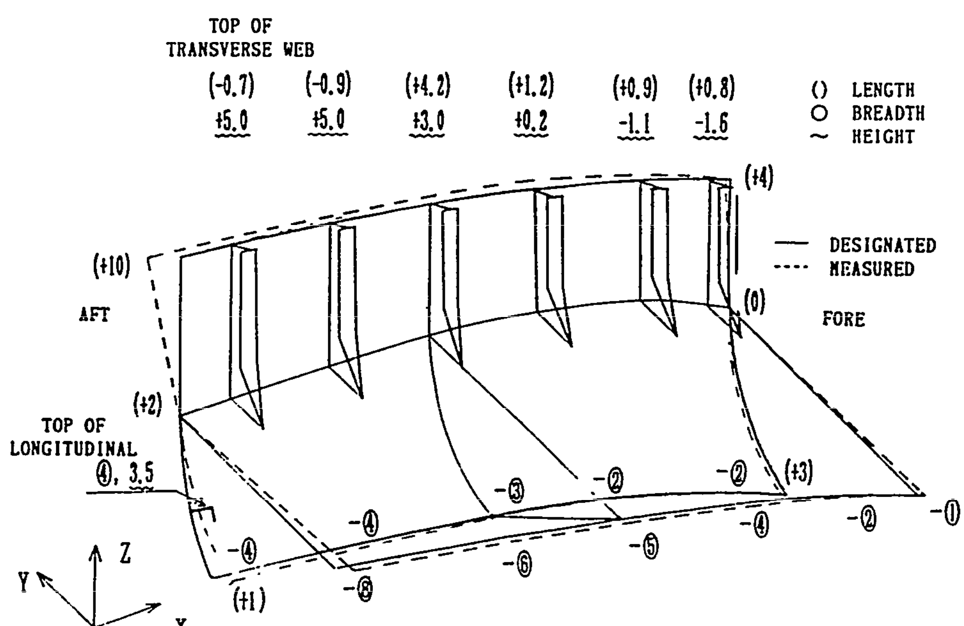


Fig. 9 EXPLANATION OF DISPLAYED RESULTS

smaller shrinkage than the expected value.

b. The breadth of the block tends to decrease at the bottom, especially at the aft. The block was found to be twisted.

c. Some dislocation of the frame top was seen in the longitudinal and vertical direction.

Actually this block was erected without correction and the detected phenomena were fed back to the next ship.

Application to Shipwright at Erection Stage

Previously, the positioning of each block at the erection stage was generally carried out in order to get good relative position with adjacent blocks and the importance of positioning a block in the ship's absolute coordinate system was not widely recognized.

Now the MONMOS system can be utilized and the policy of the shipwright has been changed to position every block onto the designated position in the absolute ship's coordinates axis one by one in favor of more accurate assembled blocks.

The following explains how the system is utilized at the erection stage in the shipyard.

a Two or three targets are attached at designated positions for shipwright on every assembled block before it is erected.

b. The absolute ship's coordinate axis is always used as a local coordinate axis of every measurement by the MONMOS system (See Fig. 10).

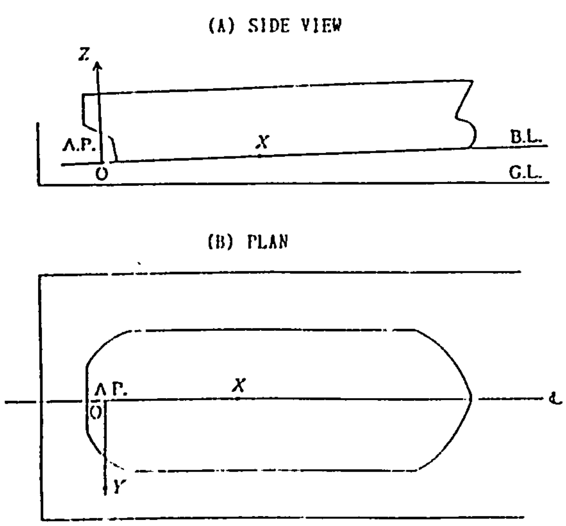


Fig.10 SHIP'S ABSOLUTED COORDINATES AXIS

c. From time to time during the process of shipwright of a block after releasing lifting wires. measurement by the MONMOS system is carried out in cooperation with shipfitters.

d. Final shipwright data of each block is transferred into the personal computer for the simulating calculation with subsequent blocks.

As blocks are positioned accurately one by one, by the new shipwright method. the extent of rework at the erection stage reduces remarkably. In addition, this method requires only one person for measurement instead of several persons as in the past. As the measurement for shipwright can be done at any convenient position using targets attached on a block beforehand, the access to higher clevation for measurement purpose is not required and this leads to safer working conditions (See Fig. 11).

Further Improvement of the Three-dimensional Analysis System

On the application of the system to actual production, accepting measurement errors to some extent cannot be avoided. These can be categorized as below.

a. Mechanical error of instrument	: Read error in vertical direction.
b. Errors during data processing	: Calculation error at combination or conversion of coordinate data.
c. Errors due to environment	
i) Heat, moisture, electricity, magnetism and etc.	: Unexpected movement of instruments.
ii) Vibration, wind, etc.	: Dislocation of instruments.
iii) Backlight, heat wave, shade, etc.	: Eye-reading errors.
d. Errors accompanied by a measuring method	: Target setting errors, error of measured angle or measured distance due to improper angle or distance.

Errors of category a. can be minimized

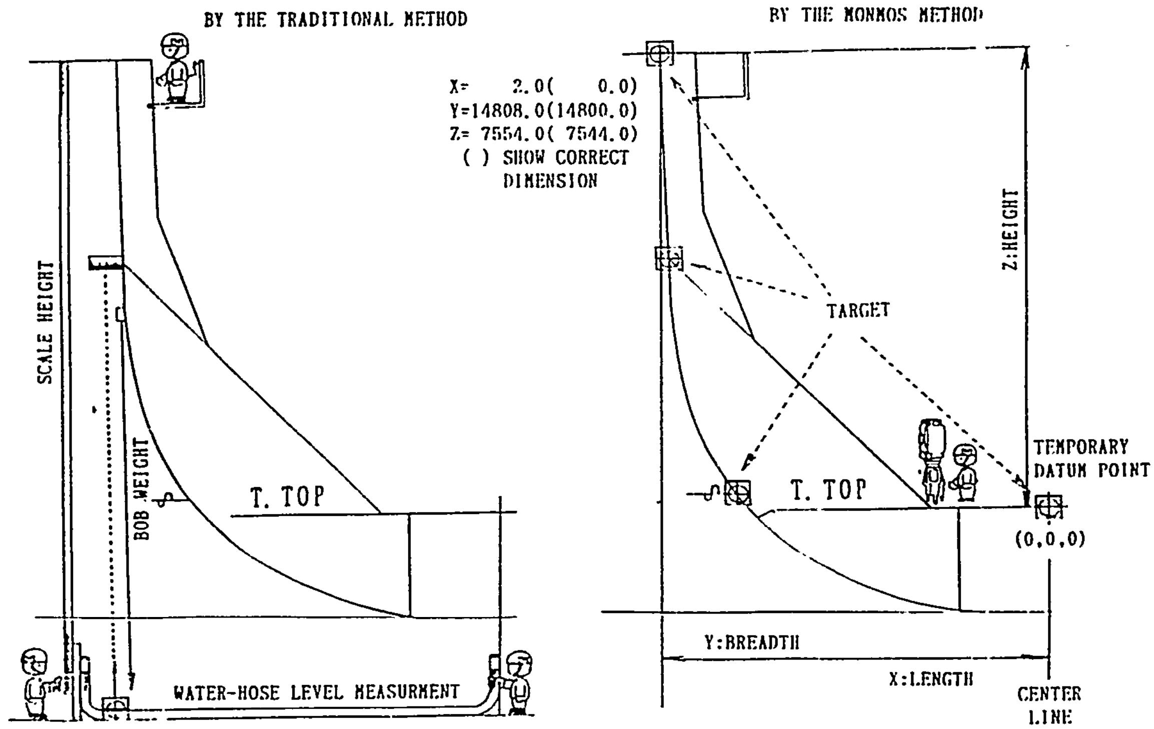


Fig.11 IMPROVEMENT OF MEASURED METHOD

depending on future improvement of the measuring instrument, while b. can be solved by improvement of the calculation software. Though a kind of an error such as category c. i) is always inevitable to almost all measurements in production sites, analyses as to cause and effect are not yet done subject to future examination. Errors such as c. ii), and iii) are expected to be reduced by preparation of a firm and covered station for the measurement, while d. is to be improved by training and education of measurers.

In addition to countermeasures to reduce the above-mentioned errors, which are rather inherent to the instrument, further improvements arc desirable on the application procedures. At the erection stage, as the combination of measured data is very often accomplished using common points for data connection, arrangement of these common points must be examined and improved by planning efforts. In assembly, it can be almost said that the accurate measuring and analyzing system of hull blocks in any size and shape has been established if numerous measurements are acceptable. However, for economical application suitable to production, there are many points to be improved further such as: determination of the minimum numbers of points on each block in order to specify the actual block shape, feeding of design data into this measuring and analyzing system in respect to the above determined measuring points, preparation of enough geometric space for measurement, scheduling to take time for the measurement, manhours saving of target fitting and so on.

CHALLENGE TO IMPROVE ACCURACY OF HULL BLOCKS

Measurement of assembled blocks by an improved method, the correction work on blocks before erection taking into account of shipwright data and a accurate shipwright method are introduced as described above. However, these are not the right way to improve the accuracy. In parallel with these, step by step accuracy improvement through various stages of work up to completion of hull blocks has been enhanced by recognizing the following two points as the right direction to solve the problem.

- Minimization of dimensional variation by mechanization.
- Accurate prediction of thermal deformation during burning or welding by simulation using numerical analysis software.

Efforts on the latter have been started

recently as a breakthrough to adjust parts data at the beginning of the data generating stage. These efforts will be reported on separately in the future after something has been established. Therefore, the approach to the former is explained hereunder.

Suggestion for Mechanization through Analyses of Variation

Fig. 12(A) and (B) show how the mean values and the standard deviations at each step of fabrication change by accumulated errors, taking block length on the skin plate and length of longitudinal stiffeners as examples. In the case of block length, it can be seen that the final deviation has been doomed before plate cutting process and the mean value changes by welding shrinkage. In the same manner, it can be said that the deviation is doomed by cutting at prefabrication process and that the mean value changes by welding shrinkage in the case of longitudinal stiffeners.

Fig. 13(A) and (B) show actual variation data of longitudinal stiffener fillet welding to the skin plate and variation of shrinkage of skin plate per one stiffener spacing due to fillet welding. From this, it is observed that fillet welding is carried out so as to keep the designated fillet size at a minimum within variation, resulting excess deposit metal and excess heat input on the average, and that the transverse shrinkage of the panel varies accordingly.

Both of the above examples are suggesting the most effective points for future action. The source work creating the above mentioned fatal variations can be mechanized or automated with great possibilities and at the same time unavoidable welding deformation and shrinkage will be able to be predicted by the simulation for feed back to original parts definition.

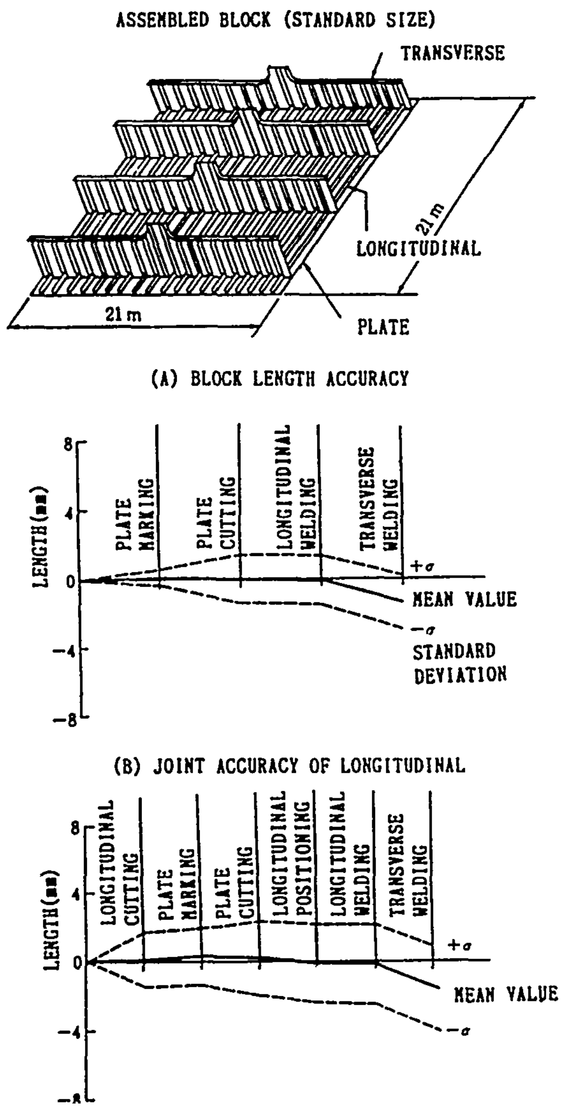


Fig.12 ACCUMULATED ERROR OF BLOCK SHARE

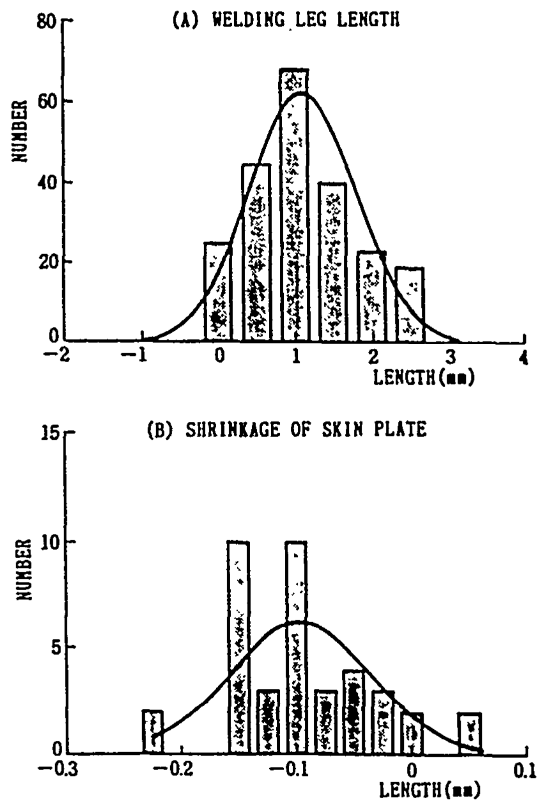


Fig.13 VARIATION OF TRANSVERSE SHRINKAGE DUE TO FILLET WELDING

Expected Improvement in the Hull Structural Work

The final goals of efforts by the new accuracy control concept, incorporated with reduction of variations by mechanization or automatization, heat deformation analysis for original adjustment of parts data and the development and application of the three-dimensional analysis system to assembly and erection stages, are placed on the following points:

- extensive manhour savings by eliminated rework,
- simplification of work by accurate parts or blocks for less dependency on skilled workers,
- higher quality of the ship itself, and
- more mechanization or automatization by more improved accuracy in continuous cyclic manner.

CONCLUSION

Accuracy control efforts in IHI supported by the new concept have been explained above. As will be accepted by everybody, this new step has been very much dependent on the materialization of an accurate three-dimensional measuring system. In this respect, the endeavor by the working group in the Shipbuilders Association of Japan especially the same by SOKKIA CO., LTD. have to be much appreciated.

A super-rationalized hull erection stage is envisioned, where adjustment burning and backing-strip fitting are no longer necessary, and a wide extent of automated work is taking place. Efforts are continuing to realize this.

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